



EVOLVING CROSS-CORRUGATED COLD FORM SHEET BASED COMPOSITE SLAB PANEL FOR EFFICIENT PEB CONSTRUCTION

A. Balaji

Research Scholar, Department of Civil Engineering, Karpagam University,
Coimbatore, Tamil Nadu, India

Dr. M. Natarajan

Professor, Department of Civil Engineering, Karpagam University,
Coimbatore, Tamil Nadu, India

Dr. A. Praveen

Professor, Department of Civil Engineering, Rajiv Gandhi Institute of Technology,
Kottayam, Kerala, India

ABSTRACT

Large number of industrial, commercial and low rise buildings is now being constructed using pre-engineered steel components. The prevailing practice of using cold-formed steel based decking slab for different type of floors required in the above mentioned buildings often disrupts normal workflow as these components are constructed using locally procured resources. Further, the deck slabs constructed in the above mentioned manner tend corrugated cold form sheet as the main flexural member and thin steel sheet attached as the liner at the bottom. The top surface is leveled using foam concrete and space between steel liner and corrugated sheet is filled using foam insulation. This paper provide performance assessment of the different type of cold form sheet designs using a finite element model developed from the experiments undertaken on deck panels currently being used. The results obtained from this research work would enable PEB manufacturers to design and use structurally efficient and cost effective cold form sheet based prefabricated slab panel system to be very heavy as an equivalent concrete slab, thus leading to the increase in the overall cost of the steel building. In order to overcome this problem, a prefabricated slab panel is introduced which consists of corrugated cold form sheet as the main flexural member and thin steel sheet attached as the liner at the bottom. The top surface is leveled using foam concrete and space between steel liner and corrugated sheet is filled using foam insulation. This paper provide performance assessment of the different type of cold form sheet designs using a finite element model developed from the experiments undertaken on deck panels currently being used. The results obtained from this research work would enable PEB manufacturers to design and use structurally efficient and cost effective cold form sheet based prefabricated slab panel system.

Key words: pre engineered buildings, cold form, FEM, decking slab, stiffness.

Cite this Article: A. Balaji, Dr. M. Natarajan and Dr. A. Praveen, Evolving Cross-Corrugated Cold form Sheet Based Composite Slab Panel for Efficient PEB Construction. *International Journal of Civil Engineering and Technology*, 8(3), 2017, pp. 402–410.

<http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=8&IType=3>

1. INTRODUCTION

The Pre-Engineered Steel Building (PEB) systems are widely used in the construction of industrial, commercial, residential and general purpose low rise building. They have become more acceptable due to suitability for large clear spans, better quality control in construction and maintenance, reduction in construction time, flexibility of expansion, architectural versatility and improved energy efficiency¹. Except for the units like mezzanine floor or external/partition walls, the significant portions of a PEB building are prefabricated. The mezzanine floors are usually made of deck slabs that are considered as composite structural unit². The deck slab is the heaviest segment of a PEB unit and in majority of buildings self weight of the deck slab will be more than total self weight of supporting steel structural system. In addition, the decking slab construction work is outsourced to local construction agency which often results in poor quality of construction or disruption of project turn over time. Thus to ensure better quality control on the construction of PEB buildings as well as to reduce project completion time, using prefabricated deck slabs in PEB construction becomes necessary. Different types of prefabricated panels available in India and their limitations are listed in Table1.

Design of the light weight prefabricated panel is governed by the serviceability condition with the design load being equivalent to load corresponding to limiting deflection^{3,4}. Several modifications like introduction of ribs on profile sheets, making the corrugation deeper, introducing reinforcing steel, bonding steel plate in the tension zone, fastening steel framing to metal deck sheet etc have been attempted to increase the flexural strength and stiffness of the panel^{11, 12, 13, 14, 15, 16}. In the case of concrete integrated PEB deck slabs, the most critical failure mode observed is the interface slip between sheeting and concrete^{5, 6, 7}. The improvement in the shear slip between concrete and the corrugated steel sheets was achieved ensuring better aspect ratio and using shear connectors^{8,9}. In addition, providing embossment on profile sheets and end anchorages using stud bolt type connectors are the other means identified for better shear bond characteristics in deck slab panels^{6,10}.

Table 1 Different type of prefabricated panels currently being used in PEB buildings

Type of Panel	Panel Dimensions Length x Width x Thickness(m)	Span provided (m)	Load Carrying Capacity (kN/m ²)	Constrains
Aerocon – aerated concrete panels	3.0x1.0x0.075	1.5	3	Very high vibration and high transportation cost.
Hollow Core Slab	3.0x1.0x0.15	1.5	7.5	Very brittle, cut /opening in the slab would adversely affect the strength.
Precast Pre stressed Concrete	3.0x1.0x0.15	1.5	12.0	High self weight, very brittle panels and high chance for crack formation.

Slab				
Timber-Concrete Composite Systems	3.0x1.0x0.25	0.6	37.0	Increased thickness, brittle panel and high cost of manufacturing.
Fiber sandwich composite panels	3.0x1.0x0.025	0.6	2.7	Low stiffness, low fire resistance, cannot be used in wet areas, high construction cost.

2. METHODOLOGY

The proposed research work was aimed to investigate the utility of cross-corrugated cold form sections for improving the load capacity of prefabricated decking slabs in PEB system. The initial investigation involved detailed experimentation to assess the structural behavior of cold-form composite panel which was introduced for improving efficiency of PEB construction¹⁶. The composite panel comprised bottom layer of single skin steel sheet and top layer of 10 mm cement boards both connected using cold form C-channel assembly (Figure 1). The total thickness of the panel would be 110 mm and the C-channel assembly, is expected to contribute to the required flexural capacity for the prefab panel. The space that exist between top cement board and bottom steel sheet is filled using foam insulation, which could also ensure adequate fire and sound insulation 3. The experimental investigation is undertaken on the complete panel unit, described above, to assess the load-deflection characteristics of PEB deck slabs. Cold form steel panels are tested as a three span continuous slab supported at four points (see figure 2) for three different panel sizes usually used for erection. The load was applied as line load along the center line of the middle span of the slab in the transverse direction and dial gauges were placed at middle point and edges to record deflection in slab. Loading is continued until load corresponding to maximum allowable deflection for that particular span of slab is reached.

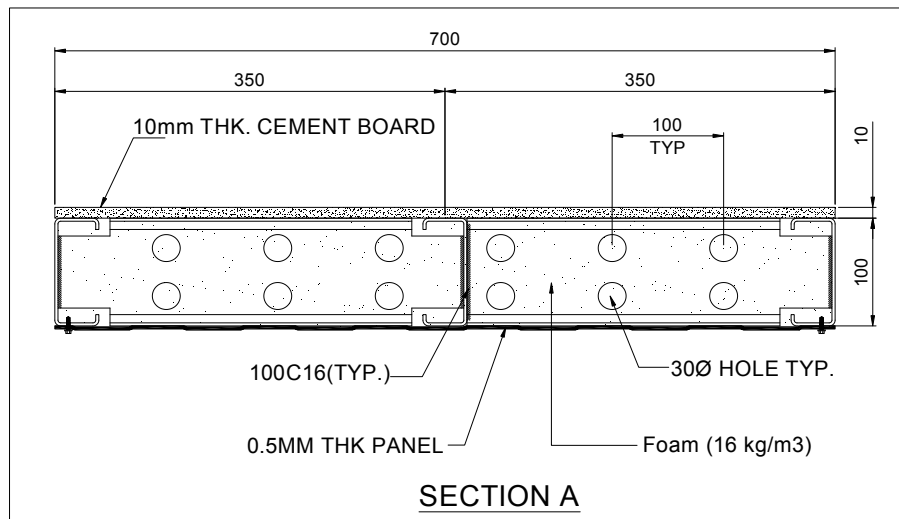


Figure 1 Components in a cold form prefab slab panel

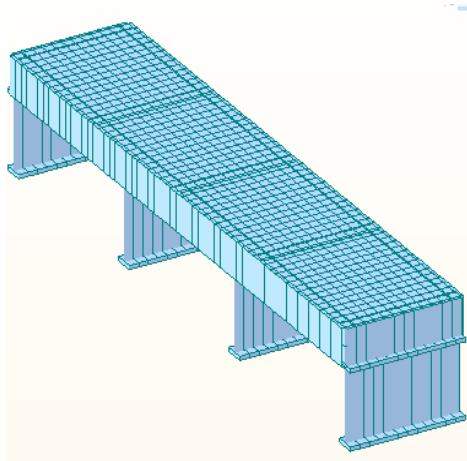


Figure 2 (a)

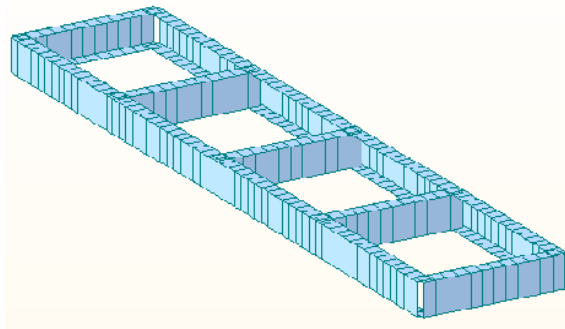


Figure 2 (b)

Figure 2 (a) FEM model of panel assembly with supporting beam **Figure 2 (b)**-FEM model of C-Channel

Added to this, a finite element model to evaluate different deck slab configuration is developed using FEM software MIDAS CIVIL v 2.2. The details of FEM model used for numerical simulation along with physical model of the slab are given in figure3. The Cold form steel panel consist of cement board on the top, insulation material to fill the inner space, C-channel assembly and bottom liner panel, which was rested on ISMB200 at 1m interval. The FEM model consist of standard plate elements for both top and the bottom layers, channel section modeled as beam element, linear eight noded solid element for filler material and hinged boundary condition. As the design of cold – form deck slab is governed by the criteria of deflection control, interventions to control the deflection and corresponding improvement to utilize the material strength is attempted by incorporating suitable changes to cold-form panels. The proposed design consists of using decking sheet in various configurations as main structural material and foam as filling material. Table 2 gives the brief description of panels used in numerical analysis to explore their utility in deck slab construction. As applied in the experimental program a line load is placed at middle portion of the panel as UDL, which is incremented by 2kN. Maximum deflection corresponding to each applied state of load is noted. The significance of decking sheets to ensure better stiffness was evaluated numerically by replacing C-channel assembly in the model with appropriate decking sheet configuration (Table 3).



Figure 3 Laboratory configuration for testing of prefabricated deck slab panels.

Table 2 Details of composite slab considered for finite element analysis

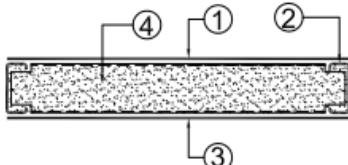
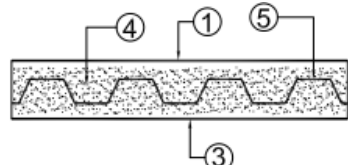
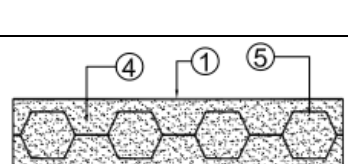
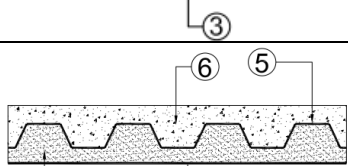
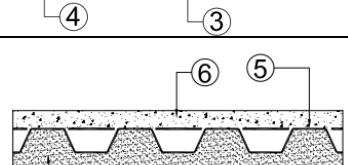

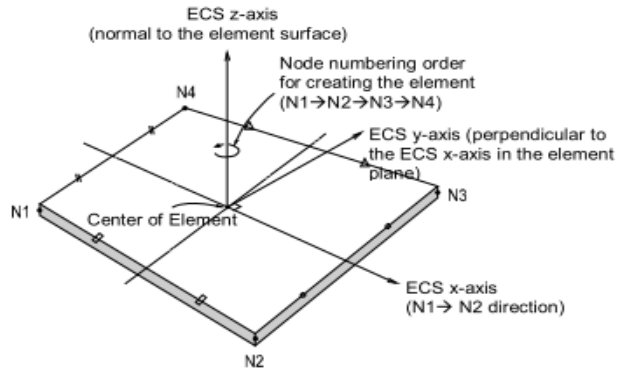
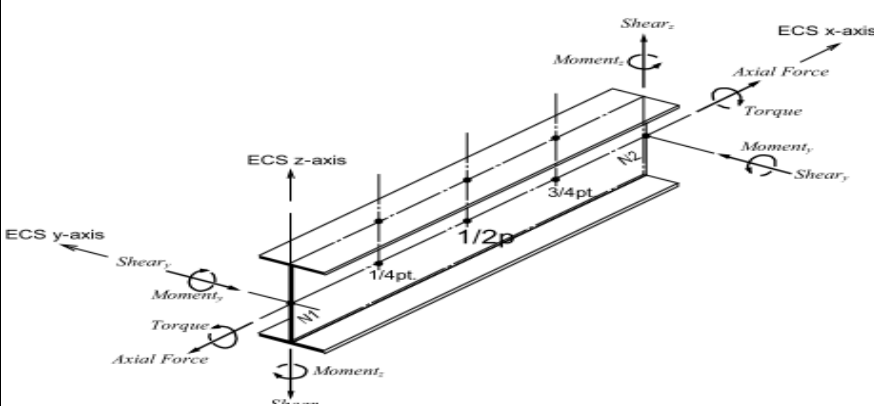
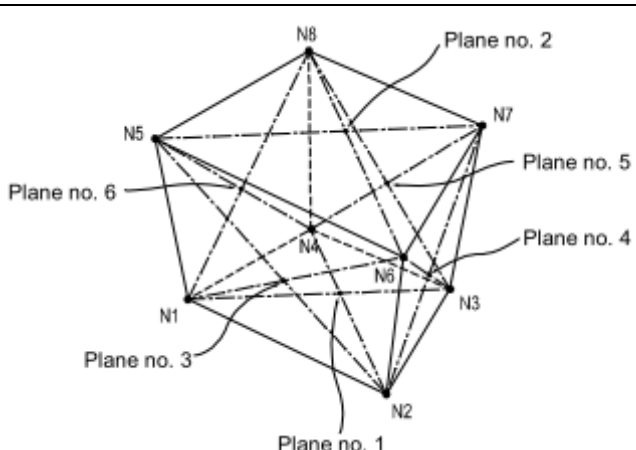
Panel Designation	Panel Dimensions Length x Width x Thick.(m)	Composite assembly						
		Top layer	Cold form configuration	Filler material	Bottom Liner	FEM configuration		
P1	3x0.7x0.1	10mm Cement Board	C-channel assembly	16kg/m ³ dense Rock wool insulation as bottom layer	0.5mm low rib steel sheet			
P2	3x0.7x0.1							
P3	1x0.7x0.1		Decking sheet with rib height 44mm					
P4A	1x0.7x0.1							
P4B	1x0.7x0.075		Decking sheet with rib height 75mm					
P4C	1x0.7x0.060							
P4D	1x0.7x0.1	600kg/m ³ dense foam concrete	2 Decking sheet with rib height 40mm					
P4E	1x0.7x0.1							
P5A	1x0.7x0.1		Decking sheet with rib height 44mm					
P5B	1x0.7x0.1		Cross Corrugated Decking sheet with rib height 44mm					

Table 3 Types of Elements used in the FEM analysis

Plate Element	 <p>4-noded plate Element</p>
Cement Board 0.5mm low rib steel sheet Corrugated Decking sheet	
Beam Element	
C-Channel Assembly	 <p>Beam Element</p>
Solid Element	 <p>Solid Element</p>

3. RESULTS AND DISCUSSION

The experiments conducted on cold form panels have helped to gather information on their performance under actual field conditions and the numerical results from different panel configurations too have helped to compare the proposed panel configurations. The results of finite element simulation of cold form steel panel deformation are compared with the experimental values mentioned earlier. Thus, the results of deformation of these panels under different loads are given separately in the figure. 4. The results from experiments and finite element analysis are found to match well and the numerical model proposed here is considered for further evaluation of different combination of composite sections. The results

hence obtained have clearly demonstrated the very low capacity utilization of the material strength. The numerical results have shown that the increase in corrugation depth and thickness of decking panels cannot ensure significant improvement of panel stiffness (Figure 5). To facilitate better sound insulation properties and to enable the top layer of panel to facilitate smooth floor finish, foam concrete is applied on the top layer of the decking sheet. The results shown in figure 6, demonstrates that corrugations in the both directions have improved the panel stiffness and performance significantly. The panels with different sizes (Table 2, panel P1, P2, P3, P4A, P4B, P4C, P4D and P4E) have behaved identically and the limiting load based on allowable deflection is found to be between 6 and 10 kN. The combination of deck sheet and foam concrete (Table 2, panel P5A and P5B) achieved better load carrying capacity up to 16kN. It is demonstrated that the better stiffening systems of cold form panels can help us to achieve better load-deflection behavior. The entire experiment was done as simply supported beam condition and one way slab unit due to profile configuration. The model performance has been compared with the different composite configurations and the cross corrugation is found to strengthen the deck panels significantly. This has made the cross corrugated panel a strong candidate for prefabricated slab systems. Also, the design symmetry and better load distribution are the major advantages achieved through these innovative components.

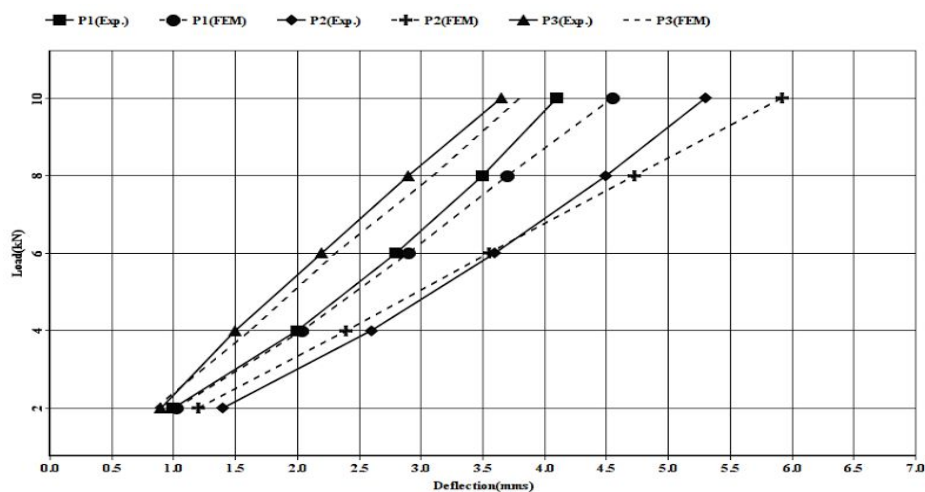


Figure 4 The experimental and numerical simulation results

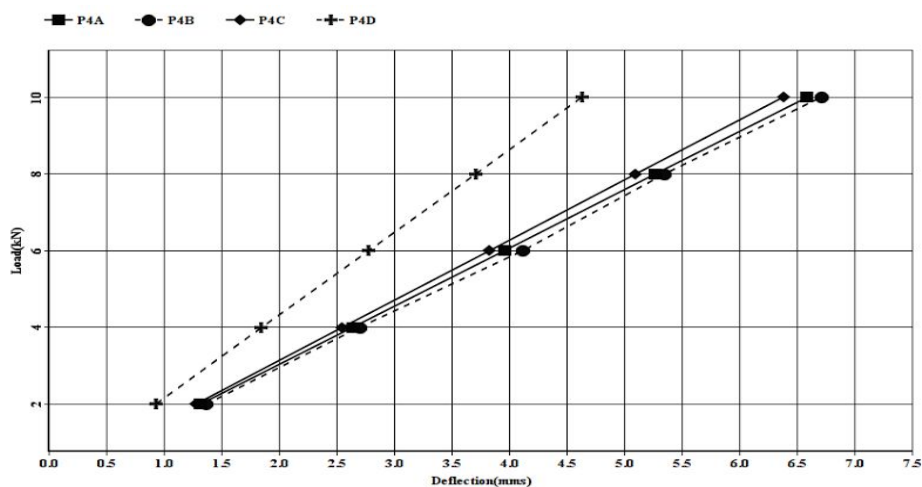


Figure 5 Load deflection plot for PEB panels obtained from finite element analysis-1

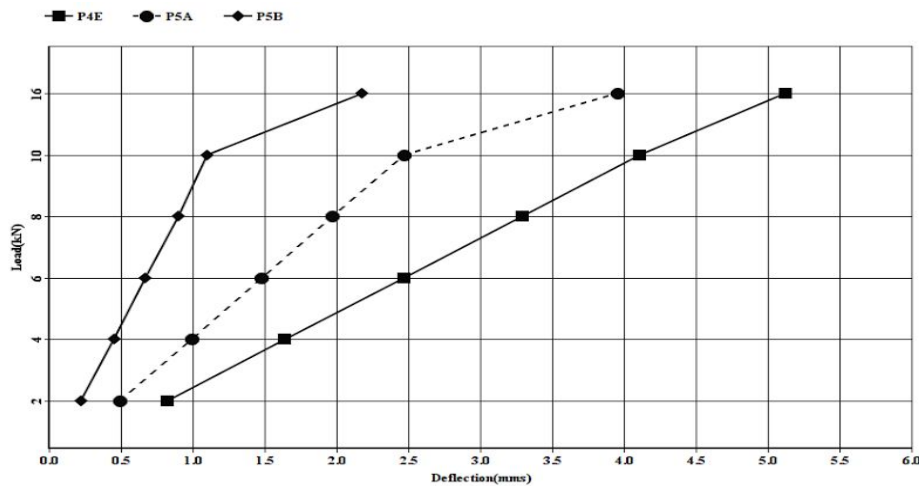


Figure 6 Load deflection plot for PEB panels obtained from finite element analysis-2

4. CONCLUSION

The paper has established the utility of ready-to-install slab, using cold-form steel panel, to eliminate the prevailing problems in the construction of the decking panel for a pre-engineered steel building. This could not only reduce the turn-over time of whole construction process but also improve the reusability of whole structural components in a PEB system. The studies on numerical model, established from the experiments undertaken on panels, have helped to arrive at cross-corrugated decking slab design. The proposed configuration which is observed to attain high strength and stiffness values and thus giving the system a better control over deflection and improved load carrying capacity. In addition, added advantage of very low weight to strength ratio, lower manufacturing cost, reduced installation time and easiness in transportation certainly make them a very attractive option. Preparing these members to take up in-plane load would make them a good choice for modular buildings for mass housing schemes in future.

REFERENCES

- [1] Firoz Syed, Kumar Sarath Chandra B & Rao S K, Design Concepts of Pre Engineered Building, International Journal of Engineering Research and applications (IJERA) ,Vol.2 ,Issue 2 (2012) 267-272.
- [2] Alexander Newman, Metal Building System, Design & Specifications 2nd ed.(McGraw-Hill Book Company, New York) ,2004.
- [3] Design Manual DM 03.10.00, (Zamil Steel Company Ltd- PEB division,(Saudi Arabia) 2000.
- [4] Specification for structural steel buildings, ANSI/AISC 360-05, (American Institute of Steel Construction, Inc), 2005.
- [5] Eldib A H, Maaly H M, Beshay A W & Tolba MT, Modelling and analysis of composite slabs, Journal of Constructional Steel Research, 65 (2009) 1236–1248.
- [6] Marimuthu V, Seetharaman S, Arul Jayachandran, Chellappan A ,Bandyopadhyay T K& D. Dutta, Experimental studies on composite deck slabs to determine the shear-bond' characteristic (m-k) values of the embossed profiled sheet, Journal of Constructional Steel Research, 63 (2007) 791–803.
- [7] Ahmed E, Wan Badaruzzaman W H, Two-way bending behavior of profiled steel sheet dry board composite panel system, Thin-Walled Structures, 40 (2002) 971–990.

Evolving Cross-Corrugated Cold form Sheet Based Composite Slab Panel for Efficient PEB
Construction

- [8] Hajir Satih Abbas, Sohaimi Abu Bakar, Mohammad Ahmadi & Zaiton Haron, Experimental studies on corrugated steel-concrete composite slab, Journal of Croatian association of civil engineers, 3 (2015) 225-233.
- [9] Vakil Merool, Kalpit Mevada & Patel Harshvadan, Experimental study on composite Deck with Different aspect ratio, Indian Journal of structural Engineering and research, Vol.3, Issue 2 (2014) 104-109.
- [10] Baskar. R & Antony Jeyasehar.C, Experimental and Numerical Studies on Composite Deck Slabs, International Journal of Engineering Research and Development, Vol.3, Issue 12 (2012) 22-32.
- [11] Yardim Yavuz, Performance of Precast Thin Panel as Permanent Formwork for Precast Composite Slabs, paper presented at 2nd International Balkans Conference on Challenges of Civil Engineering, Epoka University, Tirana, Albania, 2013.
- [12] Tim D Morrison. Innovative Low Cover Bridges Utilizing Deep-Corrugated Steel Plate with Encased Concrete Composite Ribs, paper presented at Annual Conference of the Transportation Association of Canada, Calgary, Alberta, 2005.
- [13] Zbigniew Pozorski, Rafał Sol, Jacek Szajda & Jolanta Błaszczuk, Structural Behavior of Sandwich Panels with External Deep-Profiled and Internal Soft Facing, Engineering Transactions, 61, Issue 3 (2013) 173–184.
- [14] Lakshmikandhan K N, Sivakumar P, Ravichandran R, Jayachandran A S, Investigations on Efficiently Interfaced Steel Concrete Composite Deck Slabs, Journal of structures (2013), Article ID 628759.
- [15] Seangatith, Sittichai, Experimental Investigation on Flexural Behaviors of Precast Prestressed Concrete Slabs Externally Strengthened with Steel Plates, paper presented at the Ninth East Asia-Pacific Conference on Structural Engineering and Construction, Kuala Lumpur, Malaysia, 2015.
- [16] Balaji A Raju, Dr A Praveen, Innovative cold form based composite section for enhancing sustainability in built environment, Proceedings of International Conference on Energy and Environment-2013 (ICEE 2013) , Volume 2, Special Issue 1, December 2013.
- [17] Mr. R.Divahar and Dr. P.S.Joanna. Lateral Buckling of Cold Formed Steel Beam With Trapezoidal Corrugated Web. *International Journal of Civil Engineering and Technology*, 5(3), 2014, pp. 217–225.
- [18] Dr. Nameer A. Alwash, and Ms. Dunia A. Abd Al - Radha. Theoretical Behavior of Composite Construction Precast Reactive Powder RC Girder and Ordinary RC Deck Slab. *International Journal of Civil Engineering and Technology*, 6 (12), 2015, pp. 08-21